Detailed Dose Assessment for the Two Heavily Exposed Workers in the Tokai-mura Criticality Accident

Summary of Numerical Simulation Analysis carried out as a Joint Research between JAERI and NIRS

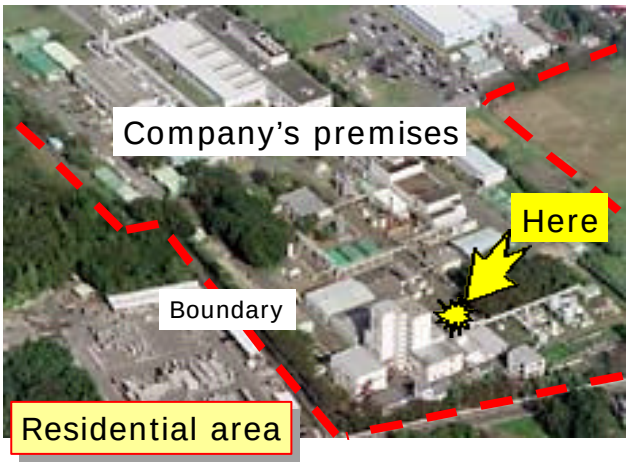
A. Endo, Y. Yamaguchi and F. Takahashi

Japan Atomic Energy Research Institute

jaeri

Where is the Accident Site?

- Uranium processing plant, JCO Co. Ltd



jaeri

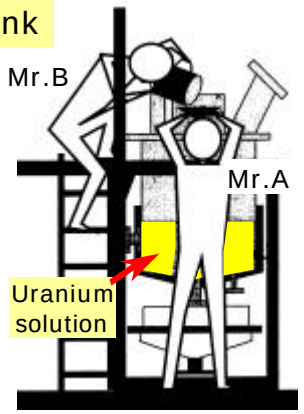
Immediate Cause of the Accident

Refining of uranium fuel for the 'JOYO'*

* Experimental fast breeder reactor

- Poured 16.6 kg uranium into a tank

7 times the allowable amount of 2.4 kg !



- Unauthorized procedure
- Insufficient knowledge about 'criticality'

jaeri

Consequences of the Accident

- The criticality continued for about 20 hours. (From 10:35, Sept. 30 to 6:30, Oct. 1)

- About 200 people within a 350 m radius were evacuated.
- About 310,000 residents living within a 10 km radius were advised to stay indoor.
- Traffic was banned in a 3 km radius.

jaeri

Summary of Radiation Doses

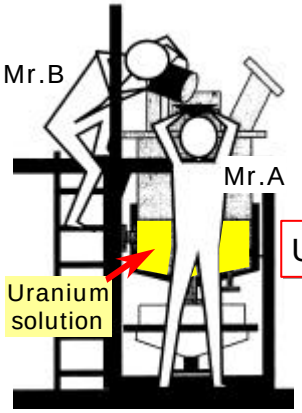
- Company's employees:
  - Three workers on the spot:
    16-20GyEq, 6-10GyEq, 1-4.5GyEq
    → The two workers passed away.
  - Other employees :
    169 persons, max. 48 mSv
- Persons involved in emergency response:
  260 persons, max. 9.4 mSv
- Residents, etc :
  234 persons, max. 21 mSv

jaeri

Necessity for Analyzing Dose Distribution

Inhomogeneous exposure by neutron & gamma-ray

Clinical progress observed in the patients



Dose Distribution
- Skin
- Trunk
- Neutron/Gamma ratio

Understanding of the biological effect

jaeri

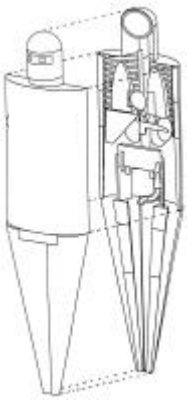
Computer Codes & Physical Data

- Computer codes:
  - ➢3-dimensional Monte Carlo codes : MCNP-4B
    MCNPX
- Radiation transport cross-section data:
  - ➢Neutron: FSXLIB-J3R2
  - ➢Photon : MCPLIB02
- Fluence-to-absorbed dose conversion data:
  - ➢Neutron : ICRU46 Kerma factor
  - ➢Photon : Energy absorption coefficient

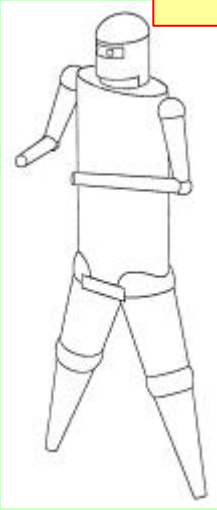
jaeri

Mathematical Phantom

MIRD phantom



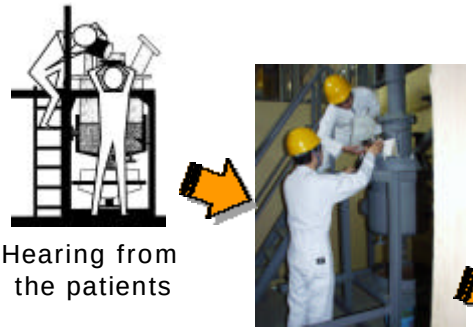
Phantom with Moveable Arms & Legs



- Tissue types
  - Lung tissue
  - Bone tissue
  - Soft tissue

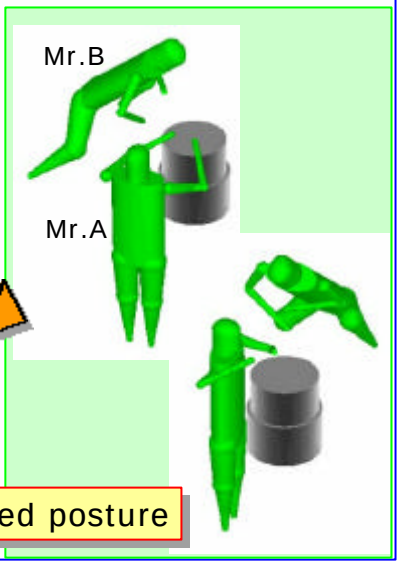
jaeri

Establishment of Calculation Geometry



Hearing from the patients

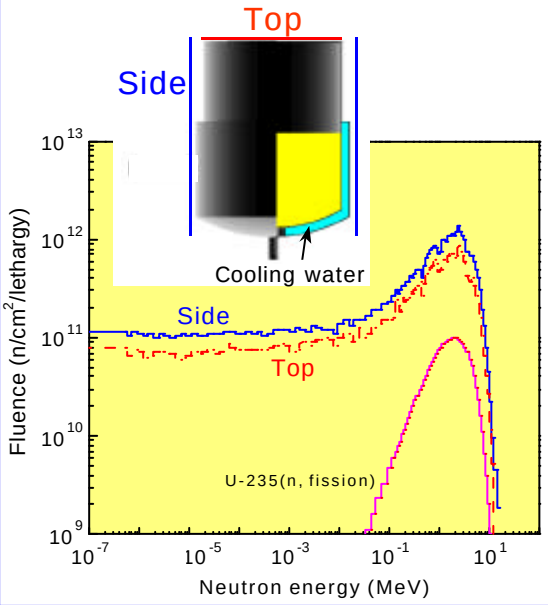
Experiment using a mock-up facility

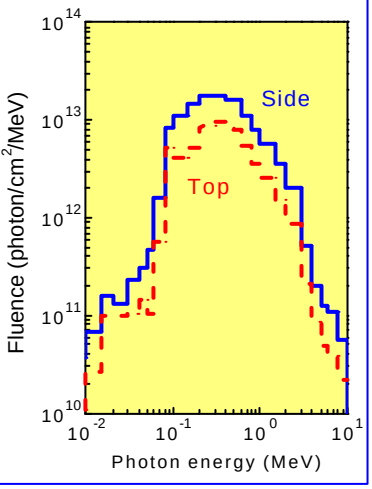


Estimated posture

jaeri

Calculated Neutron and Gamma-ray Spectra





jaeri

Absorbed Doses (Gy) in the Whole Body

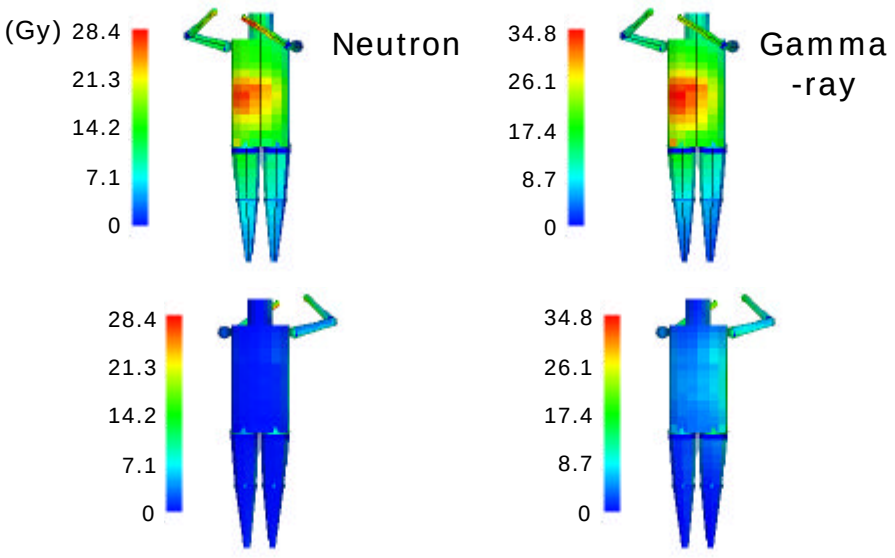
	Neutron	Gamma-ray	
		2nd gamma-rays in the body	Gamma-rays from the tank
Mr. A	5.0	1.0	10.8
Mr. B	2.6	0.6	4.4

- NIRS estimates using ^{24}Na activity and ORNL/IAEA methods

	Neutron	Gamma-ray
Mr. A	5.5	8.5 - 13
Mr. B	2.9	4.5 - 6.9

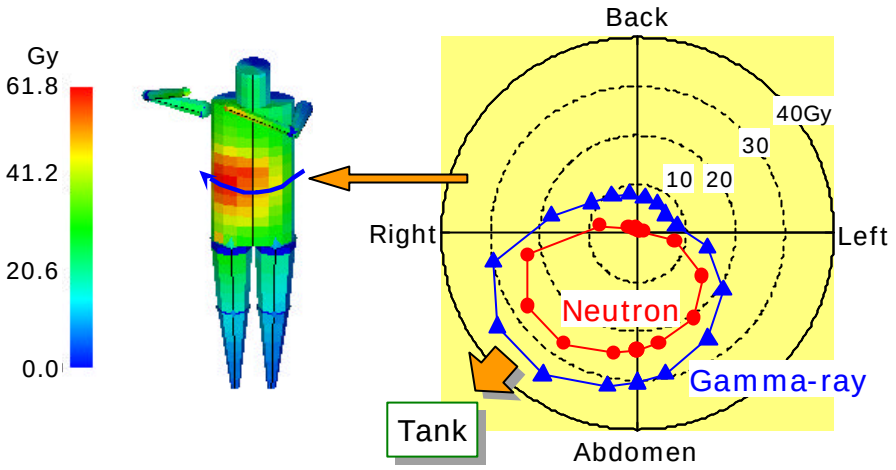
jaeri

Skin Dose Distribution of Mr.A



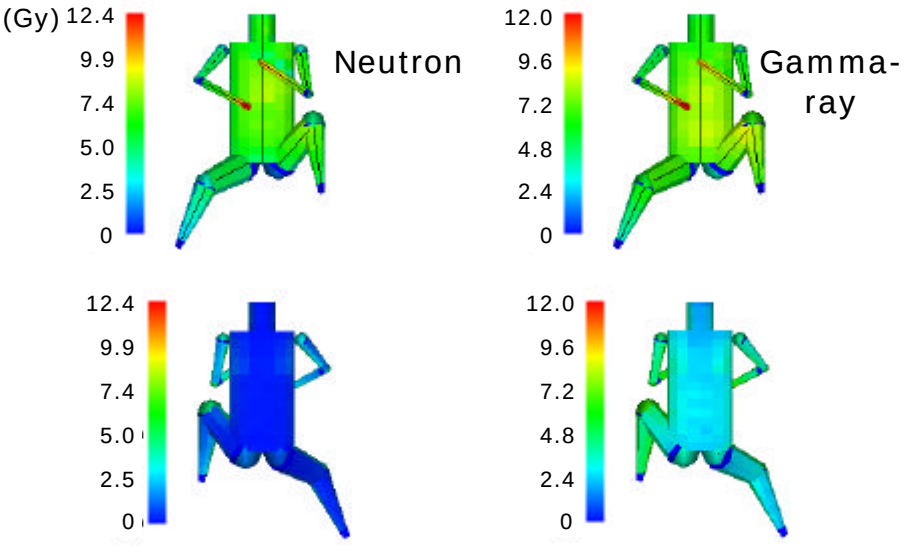
jaeri

Neutron/Gamma Ratio in Skin of Mr.A

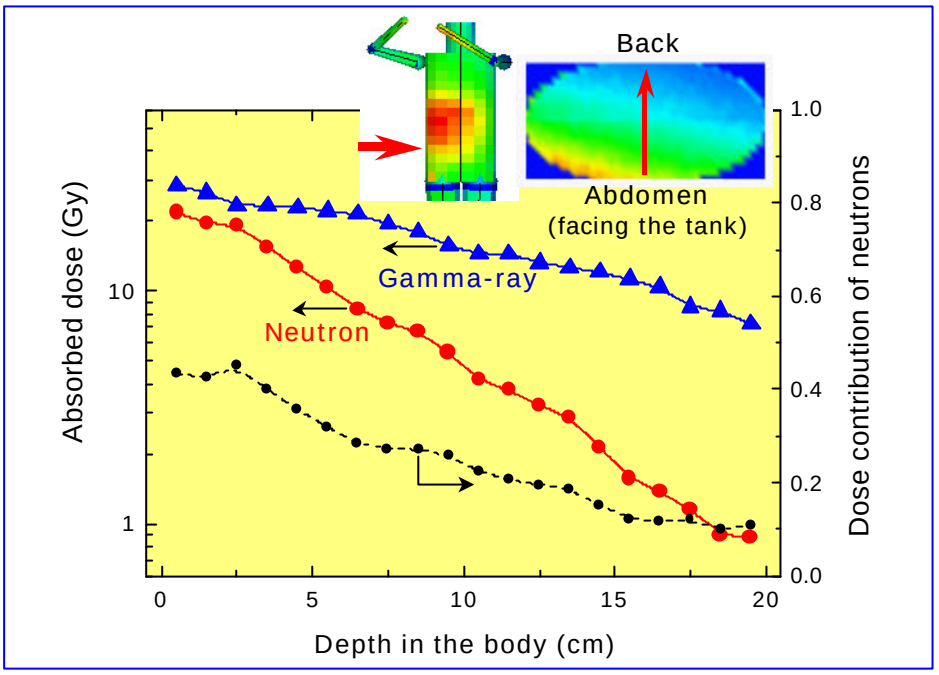


jaeri

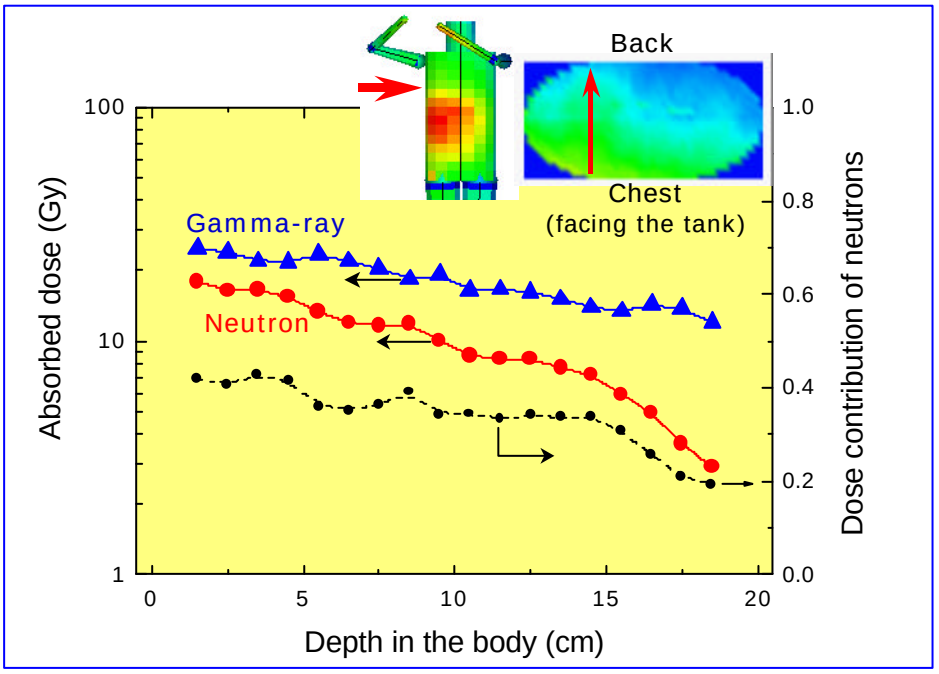
Skin Dose Distribution of Mr.B



jaeri


Back
Abdomen
(facing the tank)
Gamma-ray
Neutron
Absorbed dose (Gy)
Dose contribution of neutrons
Depth in the body (cm)
1
10
0
5
10
15
20
0.0
0.2
0.4
0.6
0.8
1.0

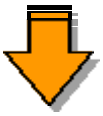
jaeri


Back
Chest
(facing the tank)
Gamma-ray
Neutron
Absorbed dose (Gy)
Dose contribution of neutrons
Depth in the body (cm)
100
10
1
0
5
10
15
20
0.0
0.2
0.4
0.6
0.8
1.0

jaeri

Summary

- Analysis of Neutron and Gamma-ray Dose Distribution using Numerical Simulation
  - Averaged dose in the whole body
  - Skin dose distribution
  - Depth dose distribution



Published in a report, JAERI Research 2001-035

- Useful for understanding of the biological effect by heavy exposure to neutrons and gamma-rays

jaeri